



**Distributed
Energy** Systems

| HYDROGEN TECHNOLOGY GROUP

Water Electrolysis Enables Renewables to Hydrogen

Wind to Hydrogen Overview with Panel Discussion

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Water Electrolysis Enables Renewables to H2

- Dispatchable
- Captures Energy as H2
- Environment – carbon free, O2 benefit
- Scaleable Architectures – stacks, modules
- Generate Pure H2 at Pressure
 - 30 bar now, higher demonstrated
 - reduce or eliminate mechanical compression

Two Commercial Water Electrolysis types

PEM – Proton Exchange Membrane

- Serial production 15 bar, 13 kg H₂/day
- Pathway to 30 bar, 500 kg/d, 980 kW, 47 kWh/kg
- **Cost-reduction leverages PEM fuel cells**



Proton HOGEN production line

Alkaline – KOH electrolyte

- Atmospheric, 100 – 1056 kg/d skids
- Pressurized 12 – 30 bar, to 144 kg/d skids
- 48 - 53 kWh/kg
- **Developing lower cost stacks, BOP**



Norsk-Hydro fueling skid for Iceland

Pressurized Water Electrolysis in North America

(an Internet search snapshot)

Proton

Commercial PEM: 13 kg/day (40 kW)

Scaling up: 100 to 500 kg/day (220 – 980 kW)

Norsk Hydro

Commercial Alkaline Technology: 5-1,000 kg/day

Developing PEM

Hydrogenics

Commercial Alkaline Technology: 2-120 kg/day

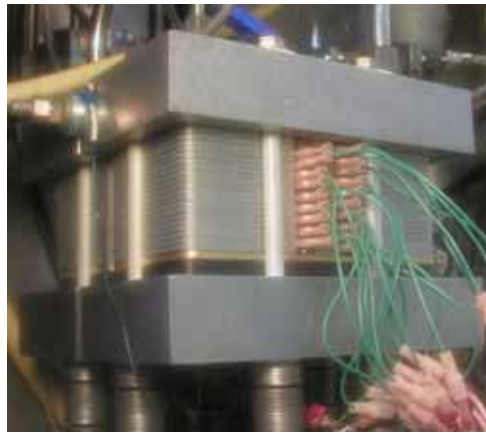
Developing PEM Technology (65 kg/day)

Teledyne

Commercial Alkaline Technology: 6-325 kg/day

GE - Developing Alkaline system

Commercial 13 kg/day PEM electrolyser

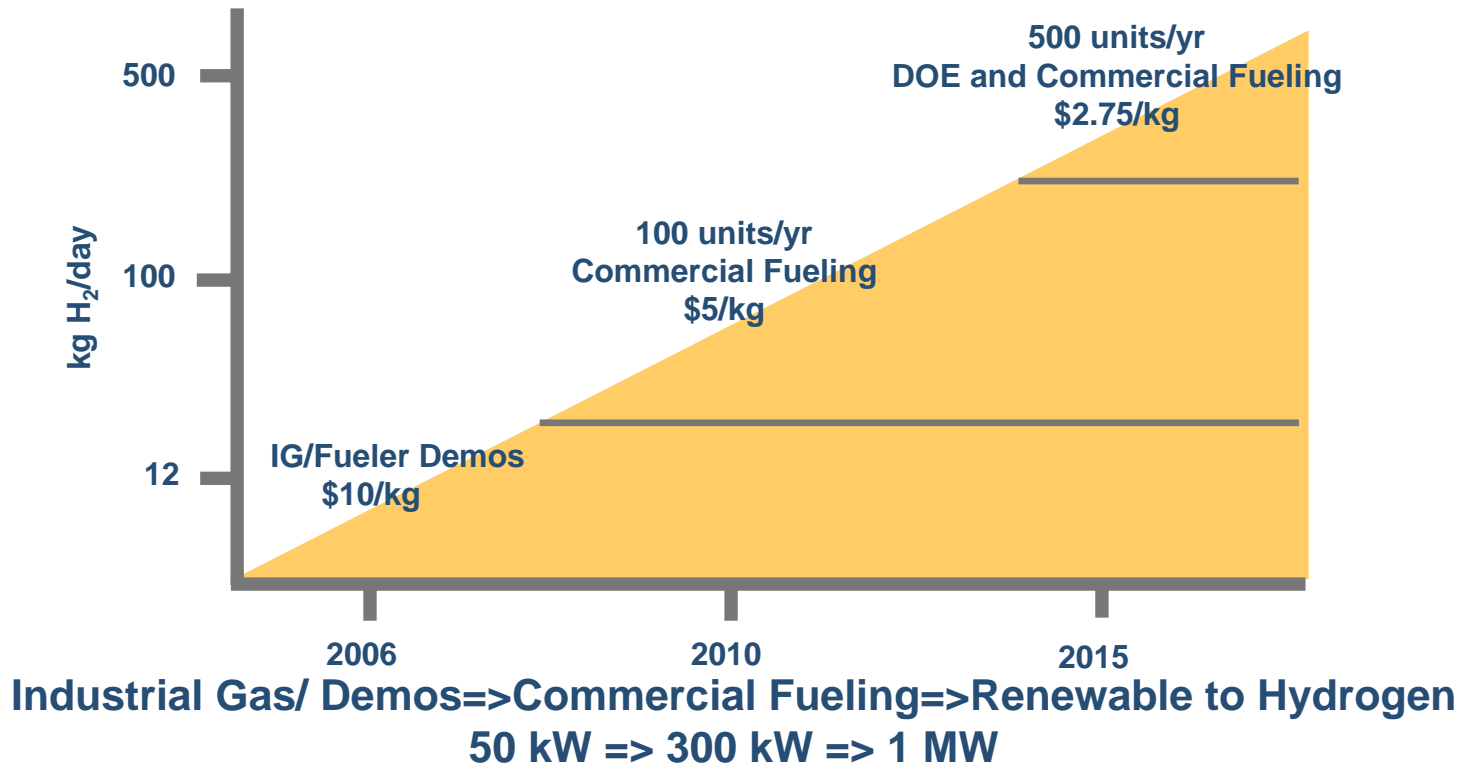


Proton's HOGEN® H2 Generator, cell stack, fueling station

Water Electrolysis Trades / Issues

- **Cost (\$/kg H₂) (\$ / kW)**
- **Scale (kW, kg/d)**
- **Pressure (bar), compression**
- **Power Conversion / Stand-Alone / Grid**
- **Availability / Turn-up : Turn-down**
- **Uniform Product Standard / Code compliance**

PEM Water Electrolysis Pathway



Fueling Metric is \$/kg H₂ ; Same Mindset as \$/gallon Gasoline

\$/kg H₂ Fuel Cost is Derived from Capital Cost, Electricity Cost, and Maintenance Cost

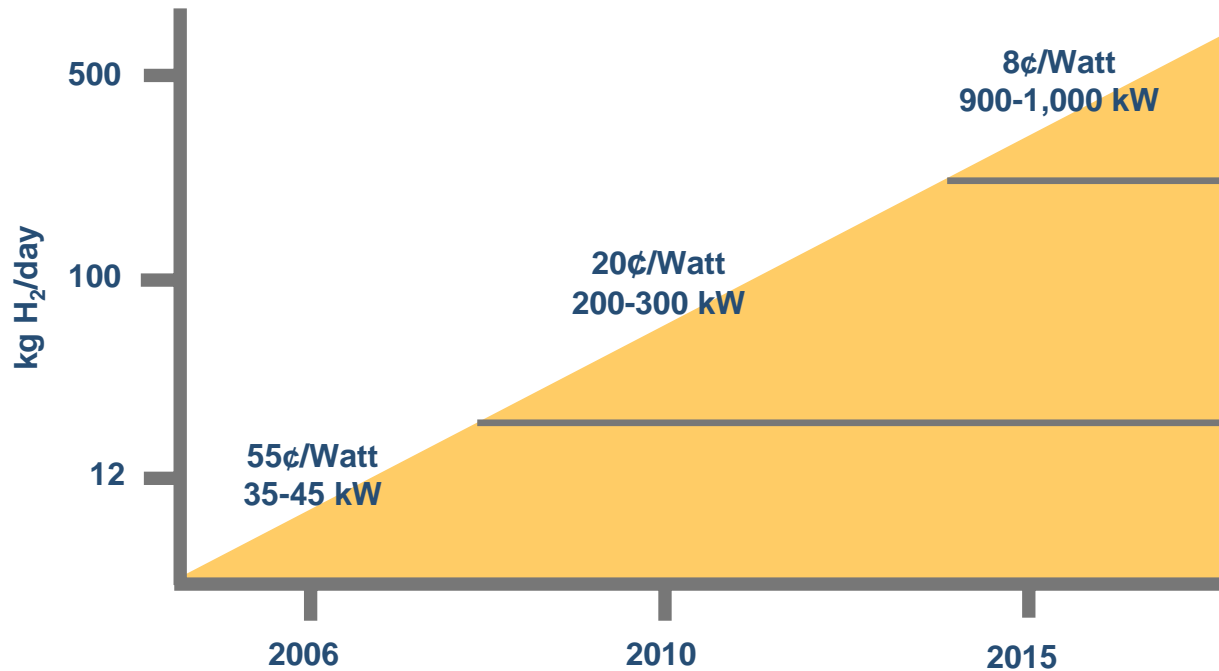
Development Pathway

Cost, Durability, Reliability, Efficiency are Keys

- **Modular, Design for Manufacture**
- **Leverage PEM Fuel Cell industry**
- **Subsystem Development**
 - Power Supply**
 - Cell Stack**
 - Balance of Plant**

Development Pathway – Power Supply

Power Supply Cost Trajectory (Estimated)



Coming - ISO, UL Electrolyser standards



DRAFT INTERNATIONAL STANDARD ISO/DIS 22734-1

ISO/TC 197

Secretariat: SCC

Voting begins on:
2005-07-29

Voting terminates on:
2005-12-29

- H₂ by Water Electrolysis
- Packaged or Factory Matched appliances
- Commercial/Industrial available technology
- Aqueous base electrolytes
- Solid polymer electrolytes
- Not covered:
 - regenerative fuel cells
 - High temperature solid oxide

ISO TC197 DIS 22734

Hydrogen generators using water electrolysis process —

- **Part 1: Industrial and commercial applications**
- **DIS => FDIS => IS by end 2007**
- Defines construction, safety and performance requirements
- **Part 2: Residential is in CD phase**

UL 2264A to adapt ISO22734 when ready